

What is claimed is:

1. A pultruded part having a uniform cross-section and a longitudinal axis, the pultruded part comprising:
 - a plurality of longitudinal rovings oriented along the longitudinal axis;
 - 5 a reinforcing structure comprising a permeable transport web of staple fibers attached to a plurality of first reinforcing fibers oriented so that the portion of the first reinforcing fibers oriented in a transverse direction comprises at least 40% of a volume of materials comprising the reinforcing structure; and
 - 10 a resin matrix substantially surrounding the longitudinal rovings and the reinforcing structure.
2. The pultruded part of claim 1 wherein the portion of the first reinforcing fibers oriented in the transverse direction comprises at least 50% of a volume of materials comprising the reinforcing structure.
- 15 3. The pultruded part of claim 1 wherein the first reinforcing fibers comprise one or more overlapping layers of first reinforcing fibers.
4. The pultruded part of claim 1 wherein the staple fibers
20 comprise a length of about ½ inch to about 4 inches.
5. The pultruded part of claim 1 wherein the staple fibers
comprise a length of about 0.01 inch to about 12 inches.
- 25 6. The pultruded part of claim 1 wherein the permeable transport web comprises heat-fusible fibers.

7. The pultruded part of claim 1 wherein the permeable transport web comprises at least two different polymeric fibers each comprising a different glass transition temperature.

5 8. The pultruded part of claim 7 wherein the at least two polymeric fibers comprise a glass transition temperature of about 350°F and about 270°F, respectively.

10 9. The pultruded part of claim 1 wherein the permeable transport web comprises:

a plurality of first polymeric fibers comprising a first glass transition temperature; and

15 a plurality of bi-component fiber wherein a first component comprises the first glass transition temperature and a second component comprises a second glass transition temperature less than the first glass transition temperature.

10. The pultruded part of claim 9 wherein the bi-component fibers comprise a core-sheath configuration.

20 11. The pultruded part of claim 1 wherein the permeable transport web comprises in-plane mechanical and directional stability.

25 12. The pultruded part of claim 1 wherein the permeable transport web comprises a plurality of fibers at least a portion of which are randomly entangled with the first reinforcing fibers.

13. The pultruded part of claim 1 wherein the permeable transport web comprises a plurality of fibers at least a portion of which are thermally bonded with the first reinforcing fibers.

5 14. The pultruded part of claim 1 wherein the first reinforcing fibers are spaced apart and attached together by a continuous stitching fibers.

10 15. The pultruded part of claim 14 wherein the stitching fiber comprises glass fibers, natural fibers, carbon fibers, metal fibers, ceramic fibers, synthetic or polymeric fibers, composite fibers (including one or more components of glass, natural materials, metal, ceramic, carbon, and/or synthetics components), or a combination thereof.

15 16. The pultruded part of claim 1 comprising a binder attaching the permeable transport web to the first reinforcing fibers.

20 17. The pultruded part of claim 16 wherein the binder comprises one or more of a specialized latex binder diluted in a water carrier, a polyvinyl acetate emulsion, and a crosslinking polyvinyl acetate emulsion.

18. The pultruded part of claim 1 comprising a plurality of perforations through the permeable transport web and extending between the first reinforcing fibers containing resin.

25 19. The pultruded part of claim 1 wherein the reinforcing structure comprises a permeability of at least $180 \text{ ft}^3/\text{minute}/\text{ft}^2$ as measured according to the procedure of ASTM D737-96 with a pressure differential of about 0.5 inch column of water.

20. The pultruded part of claim 1 wherein the reinforcing structure comprises a permeability of about 300 ft³/minute/ft² as measured according to the procedure of ASTM D737-96 with a pressure differential of about 0.5 inch column of water.

21. The pultruded part of claim 1 wherein the reinforcing structure comprises a permeability of more than 350 ft³/minute/ft² as measured according to the procedure of ASTM D737-96 with a pressure differential of about 0.5 inch column of water.

22. The pultruded part of claim 1 wherein the reinforcing structure comprises a circular bending stiffness of at least about 4 Newtons as measured according to the procedure of ASTM D4032-94.

23. The pultruded part of claim 1 wherein the reinforcing structure comprises a circular bending stiffness in a range of at least about 4 Newtons to about 15 Newtons as measured according to the procedure of ASTM D4032-94.

24. The pultruded part of claim 1 wherein the reinforcing structure comprises a thickness of about 0.004 inches to about 0.020 inches.

25. The pultruded part of claim 1 wherein the reinforcing structure comprises a thickness of about 0.010 inches to about 0.012 inches.

26. The reinforcement structure of claim 1 wherein the reinforcement structure comprises a tensile strength in the transverse direction of about 200 lbs/inch as measured using the procedure of ASTM D76-99.

27. The reinforcement structure of claim 1 wherein the reinforcement structure comprises a tensile strength in the pull direction of at least 6 lbs/inch as measured using the procedure of ASTM D76-99.

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28. The pultruded part of claim 1 wherein the first reinforcing fibers comprise glass fibers, natural fibers, carbon fibers, metal fibers, ceramic fibers, synthetic or polymeric fibers, composite fibers (including one or more components of glass, natural materials, metal, ceramic, carbon, and/or synthetics components), or a combination thereof.

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29. The pultruded part of claim 1 wherein the first reinforcing fibers comprise at least one polymeric component.

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30. The pultruded part of claim 1 wherein the first reinforcing fibers comprise a surface treatment including an organosilane agent.

31. The reinforcement structure of claim 30 wherein the organosilane agent comprises one or more families of a cationic amino-functional silane, Tris (2- methoxyethoxyvinylsilane), or 3-methacryloxypropyltrimethoxysilane.

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32. The pultruded part of claim 1 wherein the transverse direction comprises a direction about $90^{\circ} \pm 10^{\circ}$ relative to the pull direction.

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33. The pultruded part of claim 1 wherein the transverse direction comprises a direction about $90^{\circ} \pm 5^{\circ}$ relative to the pull direction.

34. The pultruded part of claim 1 wherein substantially all of the first reinforcing fibers extend continuously across a width of the reinforcing structure.

5 35. The pultruded part of claim 1 comprising a plurality of permeable transport webs attached to the first reinforcing fibers.

10 36. The pultruded part of claim 1 wherein the reinforcing structure comprises a plurality of second reinforcing fibers extending at one or more acute angles relative to the pull direction.

15 37. The pultruded part of claim 1 wherein the reinforcing structure comprises a plurality of second reinforcing fibers extending at a first acute angle relative to the pull direction and a plurality of third reinforcing fibers extending at a second acute angle that is the negative of the first acute angle.

38. The pultruded part of claim 37 comprising a plurality of fourth reinforcing fibers extending in the pull direction.

20 39. The pultruded part of claim 37 wherein the first reinforcing fibers are located between the second and third reinforcing fibers.

25 40. The pultruded part of claim 1 wherein the reinforcing structure comprises a plurality of second reinforcing fibers extending at a first acute angle relative to the pull direction, a plurality of third reinforcing fibers extending at a second acute angle that is the negative of the first acute angle, and a plurality of fourth reinforcing fibers extending generally in the pull direction.

41. The pultruded part of claim 40 wherein the permeable transport web comprises a plurality of fibers at least a portion of which are randomly entangled with one or more of the first, second, third or fourth reinforcing fibers.

5 42. The pultruded part of claim 40 wherein the permeable transport web comprises a plurality of fibers at least a portion of which are thermally bonded with one or more of the first, second, third or fourth reinforcing fibers.

10 43. The pultruded part of claim 40 wherein the first reinforcing fibers are stitched with one or more of the permeable transport web, the second reinforcing fibers, the third reinforcing fibers, and the fourth reinforcing fibers.

15 44. The pultruded part of claim 40 comprising a binder attaching the permeable transport web to one or more of the first, second, third or fourth reinforcing fibers.

45. The pultruded part of claim 40 wherein one or more of the first, second, third or fourth reinforcing fibers comprise a polymeric component.

20 46. The pultruded part of claim 40 wherein the first reinforcing fibers are located between the second and third reinforcing fibers and the fourth reinforcing fibers.

25 47. The pultruded part of claim 40 wherein the first, second, third or fourth reinforcing fibers comprise discrete layers.

48. The pultruded part of claim 1 wherein the longitudinal rovings comprise glass fibers, natural fibers, carbon fibers, metal fibers, ceramic fibers,

synthetic or polymeric fibers, composite fibers including one or more components of glass, natural materials, metal, ceramic, carbon, and/or synthetics components, or a combination thereof.

5 49. The pultruded part of claim 1 wherein the pultruded part comprises a wall thickness of about 0.045 inches to about 0.025 inches.

10 50. The pultruded part of claim 1 wherein the pultruded part comprises a wall thickness of about 0.039 inches or less.

15 51. The pultruded part of claim 1 wherein the longitudinal rovings and the reinforcing structure comprise alternating layers.

20 52. The pultruded part of claim 1 wherein the reinforcing structure is located adjacent to an outer surface of the pultruded part.

25 53. The pultruded part of claim 1 wherein the longitudinal rovings are located adjacent to an outer surface of the pultruded part.

30 54. The pultruded part of claim 1 comprising a plurality of longitudinal rovings adjacent to both surfaces of the reinforcing structure.

35 55. A pultruded part having a uniform cross-section and a longitudinal axis, the pultruded part comprising:
40 a plurality of longitudinal rovings extending along the longitudinal axis;

 a plurality of first reinforcing fibers generally oriented in a transverse direction attached to a permeable transport web, the permeably reinforcing sheet

comprising a plurality of first polymeric fibers comprising a first glass transition temperature and a plurality of bi-component fiber wherein a first component comprises the first glass transition temperature and a second component comprises a second glass transition temperature less than the first glass transition temperature;

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a resin matrix substantially surrounding the longitudinal rovings and the reinforcing structure.

56. A pultruded part having a uniform cross-section and a
10 longitudinal axis, the pultruded part comprising:

a plurality of longitudinal rovings extending along the longitudinal axis;

a plurality of first reinforcing fibers oriented in a transverse direction relative to the longitudinal axis thermally bonded to a permeable transport web so
15 that the reinforcing structure comprises a permeability of at least 180 ft³/minute/ft² as measured according to the procedure of ASTM D737-96 with a pressure differential of about 0.5 inch column of water; and

a resin matrix substantially surrounding the longitudinal rovings and the reinforcing structure.

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57. A pultruded part having a uniform cross-section and a longitudinal axis, the pultruded part comprising:

a plurality of longitudinal rovings extending along the longitudinal axis;

25 a plurality of first reinforcing fibers oriented in a transverse direction attached to a permeable transport web of staple fibers such that a ratio of a modulus of elasticity of the reinforcing structure in the transverse direction relative to a modulus of elasticity in the pull direction comprises at least 1.2; and

a resin matrix substantially surrounding the longitudinal rovings and the reinforcing structure.

58. The reinforcing structure of claim 57 wherein the ratio of the modulus of elasticity of the reinforcing structure in the transverse direction relative to the modulus of elasticity in the pull direction comprises at least 1.5.

59. The reinforcing structure of claim 57 wherein the ratio of the modulus of elasticity of the reinforcing structure in the transverse direction relative to the modulus of elasticity in the pull direction comprises at least 3.

60. The reinforcing structure of claim 57 wherein the ratio of the modulus of elasticity of the reinforcing structure in the transverse direction relative to the modulus of elasticity in the pull direction comprises at least 5.

61. A pultruded part having a uniform cross-section and a longitudinal axis, the pultruded part comprising:
a plurality of longitudinal rovings extending along the longitudinal axis;
a plurality of non-overlapping first reinforcing fibers attached to a permeable transport web of staple fibers such that the portion of the first reinforcing fibers extending in a transverse direction comprises at least 30% of a volume of materials comprising the reinforcing structure; and

a resin matrix substantially surrounding the longitudinal rovings and the reinforcing structure.

62. A pultruded part having a uniform cross-section and a longitudinal axis, the pultruded part comprising:

a plurality of longitudinal rovings extending along the longitudinal axis;

5 a reinforcing structure comprising a plurality of first reinforcing fibers oriented at 45° ($\pm 15^{\circ}$) relative to the pull direction, a plurality of second reinforcing fibers oriented at -45° ($\pm 15^{\circ}$) relative to the pull direction, and a permeable transport web of staple fibers attached to the first and second reinforcing fibers such that the first and second reinforcing fibers comprises at least 30% of a volume of materials comprising the reinforcing structure;

10 a resin matrix substantially surrounding the longitudinal rovings and the reinforcing structure.

63. A pultruded part having a uniform cross-section and a longitudinal axis, the pultruded part comprising:

15 a plurality of longitudinal rovings extending along the longitudinal axis;

a reinforcing structure comprising a plurality of first reinforcing fibers oriented at 60° ($\pm 15^{\circ}$) relative to the pull direction, a plurality of second reinforcing fibers oriented at -60° ($\pm 15^{\circ}$) relative to the pull direction, and a permeable transport web of staple fibers attached to the first and second reinforcing fibers such that the first and second reinforcing fibers comprises at least 30% of a volume of materials comprising the reinforcing structure;

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a resin matrix substantially surrounding the longitudinal rovings and the reinforcing structure.

25 64. A molded part having a uniform cross-section and a longitudinal axis, the molded part comprising:

a reinforcing structure comprising a permeable transport web of staple fibers attached to a plurality of first reinforcing fibers oriented so that the portion of

the first reinforcing fibers oriented in a transverse direction comprises at least 40% of a volume of materials comprising the reinforcing structure; and
a resin matrix substantially surrounding the reinforcing structure.

5 65. A pultruded part having a uniform cross-section and a longitudinal axis, the pultruded part comprising:
a plurality of longitudinal rovings oriented along the longitudinal axis;
a reinforcing structure comprising a permeable transport web of staple
10 fibers attached to a plurality of first reinforcing fibers oriented in a transverse direction continuously across a width of the reinforcing structure; and
a resin matrix substantially surrounding the longitudinal rovings and the reinforcing structure.

15 66. A pultruded part formed by pulling in a longitudinal direction through the die to form a part of predetermined transverse cross sectional shape comprising:
reinforcing fibers extending in the longitudinal direction;
a reinforcement mat having a length extending longitudinally of the
20 pultruded part, a width extending across at least a part of the transverse cross-sectional shape and a thickness at right angles to the length and width, the mat comprising elongated reinforcing fibers oriented in a first direction transverse to the longitudinal direction, transport components thereof arranged to provide
longitudinal strength, shear strength and anti-skewing resistance sufficient to allow
the reinforcing mat to be carried through the pultrusion die with the reinforcing
25 fibers, and entangling fibers defined by at least portions of staple fibers that extend through at least a portion of the thickness, the staple fiber portions being entangled with the reinforcing fibers; and

a synthetic resin composition enveloping the reinforcement mat and the reinforcing fibers and configured by the die to define the predetermined transverse cross-sectional shape of the part.